PC/1765

MS APPEAL BRIEF - PATENTS
PATENT
1794-0141P

IN THE U.S. PATENT AND TRADEMARK OFFICE

In re application of		Before the Board of Appeals	
Yoshinobu AOYAGI et al.		Appeal No.:	
Appl. No.:	09/941,612	Group:	1765
Filed:	August 30, 2001	Examiner:	M.J. SONG
Conf.:	6758		

For: IMPURITY DOPING METHOD FOR SEMICONDUCTOR AS WELL AS SYSTEM THEREFOR AND SEMICONDUCTOR MATERIALS PREPARED THEREBY

APPEAL BRIEF TRANSMITTAL FORM

MS APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

November 1, 2004

Sir:

Transmitted herewith is an Appeal Brief on behalf of the Appellants in connection with the above-identified application.

☐ The enclosed document is being transmitted via the Certificate of Mailing provisions of 37 C.F.R. § 1.8.

A Notice of Appeal was filed on August 30, 2004.

☐ Applicant claims small entity status in accordance with 37 C.F.R. § 1.27

The fee has been calculated as shown below:

☐ Extension of time fee pursuant to 37 C.F.R. §§ 1.17 and 1.136(a) - $0.00.

☒ Fee for filing an Appeal Brief - $340.00 (large entity).

☒ Check in the amount of $340.00 is attached.

☐ Please charge Deposit Account No. 02-2448 in the amount of $0.00. A triplicate copy of this sheet is attached.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By Joe McKinney Muncy

Joe McKinney Muncy, #32,334
P.O. Box 747
Falls Church, VA 22040-0747
(703) 205-8000

KM/RFG/mlr
1794-0141P

Attachment(s)

APPEAL BRIEF - PATENTS

PATENT
1794-0141P

IN THE U.S. PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF APPEALS

In re application of

Yoshinobu AOYAGI et al.		Appeal No.:	
Appl. No.:	09/941,612	Group:	1765
Filed:	August 30, 2001	Examiner:	M. J. SONG
For:	IMPURITY DOPING METHOD FOR SEMICONDUCTOR AS WELL AS SYSTEM THEREFOR AND SEMICONDUCTOR MATERIALS PREPARED THEREBY		
Conf:	6758		

PATENT
1422-0416P

IN THE U.S. PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF APPEALS

In re application of

Yoshinobu AOYAGI et al.		Appeal No.:	
Appl. No.:	09/941,612	Group:	1765
Filed:	August 30, 2001	Examiner:	M. J. SONG
For:	IMPURITY DOPING METHOD FOR SEMICONDUCTOR AS WELL AS SYSTEM THEREFOR AND SEMICONDUCTOR MATERIALS PREPARED THEREBY		
Conf:	6758		

TABLE OF CONTENTS

PATENT
1422-0416P

IN THE U.S. PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF APPEALS

In re application of

Yoshinobu AOYAGI et al.		Appeal No.:	
Appl. No.:	09/941,612	Group:	1765
Filed:	August 30, 2001	Examiner:	M. J. SONG
For:	IMPURITY DOPING METHOD FOR SEMICONDUCTOR AS WELL AS SYSTEM THEREFOR AND SEMICONDUCTOR MATERIALS PREPARED THEREBY		
Conf:	6758		

BRIEF ON BEHALF OF APPELLANTS

APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

November 1, 2004

Sir:

This Appeal Brief is respectfully submitted on behalf of the Appellants in connection with the above-identified application.

This is an Appeal from the Final Rejection by the primary Examiner of Claims 4-21 and 26-36 in the above-identified application, which claims were finally rejected in the Office Action dated June 15, 2004. The appealed claims 4-21 and 26-36 are set forth in the attached Appendix.

I. REAL PARTY IN INTEREST

In accordance with 37 C.F.R. § 41.37(c)(1)(i), it is submitted that the real party in interest of the present application is RIKEN of Saitama, Japan by virtue of an Assignment recorded on October 11, 2001.

II. RELATED APPEALS AND INTERFERENCES

In accordance with 37 C.F.R. § 41.37 (c)(2)(ii), it is submitted that there are no other appeals or interferences known to Appellants, the undersigned, or the Assignees that will directly affect or be directly affected by or have a bearing on the Board's decision in the present appeal.

III. STATUS OF THE CLAIMS

Claims 1-3 are cancelled.

Claims 4-21 and 26-36 are rejected and appealed. Claims 4-21 and 26-36 are set forth in the attached Appendix.

Claims 22-25 are withdrawn.

IV. STATUS OF AMENDMENTS

No Amendments have been filed subsequent to the final rejection.

V. SUMMARY OF CLAIMED SUBJECT MATTER

Method in General

The present invention is directed to a method of making a multi-layered semiconductor material. As seen in Fig. 3, a series of layers made of crystal materials A and B alternate on top of substrate. Impurity materials C and D are incorporated in the crystal materials. In particular, impurities C and D form impurity pairs as a donor-acceptor complex. As described on pages 1 and 2 of the specification, previous methods have tried a similar arrangement, but the materials are continuously supplied so that the p-type impurities and the n-type impurities cancel each other.

The present invention overcomes these problems by controlling the time of introduction of the impurity materials. As a result, the impurities should not cancel each other, the carrier concentration becomes higher (page 24, line 10) and the activation energy is decreased (page 22, line 11).

As seen in Fig. 2, raw materials A and B are provided at times t_A and t_B with purge times therebetween. Impurities C and D are both provided before the raw material B and are close to each other in time. The impurities are only provided for a short time period and not continuous. As indicated on page 12 starting at line 3, C and D can be supplied along with crystal material A or supplied after starting the crystal material A or before starting the supply of crystal material B. In any case, impurity C and impurity D

should be supplied close in time. Due to the timing of the supply of the impurities, an improved material is formed.

Independent Claim 26

Independent claim 26 describes the doping method where the crystal layer is made of crystal raw materials and doping impurities. The first step of the method is supplying the crystal material one at a time, separated by purge time in one cycle. The second step is supplying each of plural types of impurity raw materials for a given time where the times for each raw impurity material are close to each other. The third step is forming impurity pairs as a donor-acceptor complex using co-doping to cause a decrease in activation energy and in increase in carrier concentration.

This method can be seen in Figs. 2 and 3, where the supplying of the raw materials are shown in the first two lines of Fig. 2 and where the purge times are indicated by T_{pa} and T_{pb}. The second step of supplying the impurity materials are shown in lines 3 and 4 of Fig. 2. The layers which are formed are shown in Fig. 3. The formation of impurity pairs and the resultant to decrease in activation energy and increase in carrier concentration is described in the specification on pages 14, 22 and 24 as discussed above. Also, the graphs in Figs. 9 and 10 and the corresponding discussion, especially on page 25 of the specification, further describes this feature. Figs. 7 and 8 show a specific example corresponding to Figs. 2 and 3 also.

Independent Claim 27

Claim 27 has similar steps to claim 26, but refers to the crystal materials as "plural types" in the preamble and also in the first step. The second step is similar but refers to the given times of the impurity materials as being either at the same time of or after the start of supplying the crystal materials and in either case before starting the supply of the other crystal material. The third step is similar to that of claim 26. The different times for the impurity materials is discussed, especially in the first full paragraph of page 14 and to some extent on page 13. The remaining steps are described at the same location indicated in regard to claim 26.

Independent Claim 28

The preamble and third step of claim 28 are similar to claim 27. The first step specifically describes first and second crystal materials being alternatively supplied with purge times between the supply of these two crystal materials. The second step provides the supply of two raw materials at given times where these given times are close to one another (similar to the language of claim 26) and either at the same time or after the start of supplying the first raw material and either case before starting supplying the second raw material (similar to the language of claim 27). Thus, the steps of claim 28 are supported in the same manner as claims 26 and 27.

Independent Claim 21

Claim 21 refers specifically to the example provided in Figs. 7 and 8. The claim describes a cycle as including a first step describing the supply of TMGa and ((Cp_2Mg), which corresponds to the first time period starting at T1 in Fig. 7. The second step describes the supply of TESi which is shown in the fifth line of Fig. 7. The third step describes the supply of ammonia which is in the second line of Fig. 7. The fourth step describes a purge time which is indicated by T_{pb} between the second and third lines of Fig. 7. The description of the impurity pairs is the same as found in claims 26-28.

Dependent Claim 4

This claim depends from claim 28 and further describes the supply of the impurity material. This is also shown in Fig. 2 in the third and fourth lines. This timing in specifically described in the first full paragraph on page 12.

Dependent Claim 5

Claim 5 depends from claim 28 and further describes the timing of the raw materials as being at the same time. This is described in the fourth full paragraph on page 13.

Dependent Claims 6-10

These claims specifically describe the crystal raw materials

by way of two Markush groups. This is described on page 5 in the second full paragraph and in the paragraph bridging pages 26 and 27. These claims have a similar recitation but depend from different claims and are accordingly grouped with the claims from which they depend.

Dependent Claims 11-20

Each of these claims recites that the impurity raw materials are a p-type material and an n-type material. This is found in the specification on page 5 in the third full paragraph and on page 11 in the second full paragraph. These claims all have a similar recitation but depend from different claims. These claims are accordingly grouped with the claims from which they depend.

Dependent Claims 29-32

These claims further describe the impurity materials as being placed at a close relationship and at a predetermined ratio without incorporating disorder. In the case of claim 32, the specific materials are described rather than the generic terminology. The features of these claims are described in the second full paragraph on page 24. It is also described in the first full paragraph on page 22. Each of these claims should be considered as a separate group since they depend from different claims and include a feature not shown in the references.

Dependent Claims 33-36

These claims recite that the impurity materials are supplied in a pulsed manner. In regard to claim 36, the specific materials are described. This feature is described in the second paragraph on page 24. It is also seen in the time graphs of Figs. 2 and 7. These claims have similar recitations but depend from different claims and accordingly should be considered as separate groupings since they include another feature not seen in the references.

VI. GROUNDS OF REJECTION

Claims 4-21, 26-28 and 33-36 stand rejected under 35 USC §103(a) as being obvious over Nishizawa et al. (US Patent 5,693,139) in view of Edmond et al. (US Patent 5,739,554).

Claims 21 and 33-36 stand rejected under 35 USC §103(a) as being obvious over Nishizawa et al. (US Patent 5,693,139) in view of Edmond et al. (US Patent 5,739,554) and further in view of Manabe et al. (US Patent 6,472,690).

Claims 29-32 stand rejected under 35 USC §103(a) as being obvious over Nishizawa et al. (US Patent 5,693,139) in view of Edmond et al. (US Patent 5,739,554) and Daly (US Patent 5,231,298).

VII. APPELLANTS' ARGUMENTS

1. Nishizawa et al. in view of Edmond et al.

The Examiner relies on Nishizawa et al. to show a method of growing semiconductor monolayers with the supply of Ga and As, with the chamber evacuated between these two supplies. Impurity gases of either p-type or n-type can be used for doping. The Examiner admits that Nishizawa et al. does not disclose that the given times for supplying each of the impurity raw materials are close to each other.

In regard to Edmond et al., the Examiner states that the reference shows a GaN layer which is co-doped with both a group II acceptor and a group IV donor. The Examiner feels that it would have been obvious to modify Nishizawa et al. with the teachings of Edmond et al. to form a co-doped GaN layer. However, the Examiner admits that the combination of these two references is silent as to the forming of impurity pairs within at least one of the crystal raw materials. The Examiner feels that the combination of the two references teach supplying similar materials and impurities so that this feature would be inherent.

In order to support the argument of inherency, the Examiner mentions two additional references Pankove (US Patent 4,028,720) and Anayama et al. (US Patent 5,799,027). However, since these two references have not been applied by the Examiner and are not part of the rejection, Applicants submit that the Examiner is incorrect in relying on these reference as evidence of inherency.

The Examiner furthermore states that the combination of Nishizawa et al. and Edmond et al. does not teach the decrease in activation energy and increase in carrier concentration, but that these would also be inherent.

Independent Claim 26 and Dependent Claims 6, 11 and 16

Claim 26 states that the given time for supplying the impurity raw materials are close to each other. The Examiner admits that this is not seen in Nishizawa et al. The Examiner relies on Edmond et al. to show this feature by teaching the co-doing of an acceptor and donor within a gallium nitride layer. Applicants disagree that this teaching of Edmond et al. to show the co-doping reads on the time for supplying the raw materials being close. Edmond et al. does not disclose any method steps at all. Instead, all that is disclosed is the product having a series of layers. The fact that co-doping is taught does not indicate that the time for supplying the impurity materials are close to each other. As discussed on page two of the specification, co-doping is possible with continuously supplying impurities. Since Edmond et al. does not indicate that the supply times are close to each other, Applicants submit that the reference does not teach this feature merely by showing co-doping in general. Furthermore, column 4, line 63 of Edmond et al. refers to the "net conductivity type" which sounds similar to the description to page 2 of the specification of the compensation effect so this would teach away from the impurity

materials being close to each other and instead teaches toward a continuous supply. Accordingly, since the reference does not show the given times for the impurity materials being close to each other, Applicants submit that claim 26 is not obvious over this combination of references.

Furthermore, the final paragraph of claim 26 describes the donor-acceptor complex causing a decrease in activation energy and an increase in carrier concentration. The Examiner admits that the combination of the two references does not teach this feature. The Examiner relies on inherency to teach the features of the final paragraph of claim 26. Applicants submit that this is incorrect. As indicated on page 2 of the specification, it is possible to have co-doping without these features. Applicants submit that since neither reference teaches these features, they would not be inherent especially in view of the fact that other types of co-doping are possible which utilize a different method. Accordingly, the attainment of these results would not necessarily occur from the teachings of Edmond et al. even if combined with Nishizawa et al. Accordingly, Applicants submit that claim 26 is allowable for this reason as well.

Claims 6, 11 and 16 depend from claim 26 and are allowable based on their dependency.

Independent Claim 27 and Dependent Claims 7, 12 and 17

Claim 27 is similar to claim 26 but specifically describes plural types of crystal materials and states that the given times of the impurity materials are either at the same time of or after the start of the supply of the crystal materials and in either case are before the starting supply of the crystal material. Although this feature is different than in claim 26, Applicants submit that Edmond et al. also does not also show this arrangement of the given times. Just as in claim 26, Edmond et al. does not discuss the method steps but only the final product. Also, in a similar fashion claim 26, this arrangement of times is not inherent based on the showing in Edmond of the final product. Accordingly, Applicants submit the claim 27 is likewise allowable as neither of the references nor any other combination suggest these given times for the supplying of the impurity materials.

The final paragraph of claim 27 is allowable for the same reasons as recited above in regard to the final paragraph in claim 26.

Claims 7, 12 and 17 are likewise allowable based on their dependency from claim 27.

Independent Claim 28 and Dependent Claims 8-10, 13-15 & 18-20

Claim 28 is similar to claims 26 and 27 but describes in the second step that the given times are both close to one another and

either at the same time of or after the start of supplying of the first crystal material as well as before the starting of the supply of the second crystal material. This is a combination of the given times from claim 26 and claim 27. Applicants submit that this step where the given times are combined from claim 26 and 27 are not taught in either of the references for the same reasons recited above in regard to claim 26 and 27.

The final paragraph of claim 28 is the same as the final paragraph of claims 26 and 27. This claim is further allowable for the reasons recited above in regard to those two claims.

Dependent claims 8-10, 13-15 and 18-20 are also allowable based on their dependency from claim 28.

Independent Claim 21

Claim 21 follows the same format as claims 26-28, but includes four steps which are repeated for a cycle which relate to the four time periods shown in Fig. 7. In particular, the second step discusses the timing of the supply of TESi, which is the second impurity material. This was not disclosed at all in Edmond, as discussed above in regard to claims 26-28. As discussed above, Edmond et al. does not state in any manner the timing of the supply of the impurity materials. Accordingly, Applicants submit that this claim is not obvious over the combination of the two references.

Furthermore, the next to the last paragraph of this claim is the same as in claims 26-28 and is also allowable for the reasons recited above in regard to those claims.

Dependent Claim 4

Dependent claim 4 depends from 28 and further describes the time of the supplying of the two impurity materials. As discussed above in regard to the independent claims, the references do not show the timing of the impurity materials and accordingly this claim is additionally allowable.

Dependent Claim 5

Claim 5 is also a dependent claim which discusses the relationship of the times of supply of the two impurity materials. This is also not shown in the references for the same reasons as discussed above. Accordingly, claim 5 is additionally allowable.

2. Nishizawa et al. in view of Edmond et al. and Manabe et al.

Independent Claim 21

Claim 21 is again rejected over this three-way combination of references. The Examiner relies on Manabe et al. to show the use of TESi in the three-way combination, rather than stating that its

use would be obvious. First, Applicants submit that the combination of three references is even less obvious than the combination of the two references. Furthermore, even if Manabe et al. does teach the use of TESi, Applicants submit that three references still do not teach the control of the supply times as claimed for the reasons recited above in the rejection of claim 21 over the two-way combination of references. Accordingly, Applicants submit that claim 21 is not obvious over the three-way combination of references.

Dependent Claims 33-36

In regard to claims 33-36, the Examiner states that Manabe et al. teaches supplying reactants for a short period of time. Applicants submit that merely providing materials for only a short period of time is not the same as a pulsed manner as used in the claim. As seen in Figs. 2 and 7, the supply of the materials is quickly turned on and off not just once but in sequence to form a repeating cycle. Applicants submit that this is not the same as shown in Manabe et al. Further, Applicants submit that it would be even less obvious to combine this additional reference with the two other references. Further, each of these references depends from an allowable claim and as such are also considered to be allowable.

Although the limitations described in these four claims are similar, each forms its own group since it depends from a different

independent claim which is allowable due to the different features in each independent claim.

3. Nishizawa et al. in view of Edmond et al. and Daly

Dependent Claims 29-32

Claims 29-32 describe the close relationship between the raw materials and having a predetermined ratio without disorder. The Examiner cites Daly et al. to teach an epitaxial deposition of a strain-free p-layer that includes the balancing of the strain of the crystal lattice structure. Even if this reference does teach these features, Applicants submit that these claims are allowable over the three-way combination since the Examiner has not stated that the reference shows the close relationship nor does it teach the predetermined ratio nor the lack of disorder. The Examiner has assumed that having a strain-free layer is equivalent to the lack of disorder. Applicants submit that this is not the case and that the Examiner has not met his burden by explaining how this teaching is the same as the claimed features.

Furthermore, these claims each depend from allowable claims and as such are also considered to be allowable. Furthermore, Applicants submit that this three-way combination is less obvious than the two-way combination discussed above. Since the Examiner has not taught any motivation for combining the teachings of Daly with the other two references, Applicants submit that these claims are not obvious over the three-way combination.

Although the limitations of these claims are similar, they should be considered in separate groupings since they depend from claims which have different features.

4. Nishizawa et al. in view of Edmond et al. and Manabe et al. and further in view of Daly

Claim 32

Claim 32 is rejected over the four-way combination of references. Applicants submit that there is no motivation for combining the four references. Accordingly, this combination is even less obvious than the other combinations. Applicants submit that claim 32 is not obvious since there is no reason to combine these four different teachings.

Furthermore, claim 32 is allowable based on its dependency from claim 21. Further, as explained above, none of the references teach the close relationship, the predetermined ratio, and the lack of disorder. As discussed above, Daly does not teach these features and the Examiner has not even stated that they are shown. Accordingly, Applicants submit that claim 32 is not obvious over these references.

VIII. CONCLUSION

In view of the above Applicants submit that the Examiner's Rejections are in error and Applicants request that the Examiner's rejection be reversed and the Application allowed.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By

Joe McKinney Muncy, Reg. 32,334
P.O. Box 747
Falls Church, VA 22040-0747
(703) 205-8000

KM/RFG/mlr
1422-0416P

Attachment: CLAIMS APPEALED APPENDIX
EVIDENCE APPENDIX
RELATED PROCEEDINGS APPENDIX

APPENDIX A

CLAIMS APPEALED APPENDIX

4. An impurity doping method for semiconductor as claimed in claim 28 wherein:

a supply of said first impurity raw material is started in synchronous with starting a supply of said first crystal raw material, a supply of said second impurity raw material is started after finishing the supply of said first impurity raw material, and the supply of said second impurity raw material is finished before starting the supply of said second crystal raw material.

5. An impurity doping method for semiconductor as claimed in claim 28 wherein:

there is a period of time wherein said first impurity raw material is supplied with said second impurity raw material at the same time.

6. An impurity doping method for semiconductor as claimed in claim 26 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material is supplied latterly within said one

cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

7. An impurity doping method for semiconductor as claimed in claim 27 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se and Te.

8. An impurity doping method for semiconductor as claimed in claim 28 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se and Te.

9. An impurity doping method for semiconductor as claimed in claim 4 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

10. An impurity doping method for semiconductor as claimed in claim 5 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

11. An impurity doping method for semiconductor as claimed in claim 26, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

12. An impurity doping method for semiconductor as claimed in claim 27, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

13. An impurity doping method for semiconductor as claimed in claim 28, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

14. An impurity doping method for semiconductor as claimed in claim 4 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

15. An impurity doping method for semiconductor as claimed in claim 5 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

16. An impurity doping method for semiconductor as claimed in claim 6 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

17. An impurity doping method for semiconductor as claimed in claim 7 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

18. An impurity doping method for semiconductor as claimed in claim 8 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

19. An impurity doping method for semiconductor as claimed in claim 9 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

20. An impurity doping method for semiconductor as claimed in claim 10 wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

21. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

a cycle composed of:

a first step wherein a supply of trimethylgallium (TMGa) and biscyclopentadienyl magnesium ($(Cp)_2Mg$) is started at a first timing, and the supply of TMGa and $(Cp)_2Mg$ is finished at a second timing at which the supply TMGa and $(Cp)_2Mg$ for a predetermined period of time was completed;

a second step wherein a supply of tetraethylsilane (TESi) is started either immediately after, or after the second timing at which the supply of TMGa and $(Cp)_2Mg$ was finished, and the supply of TESi is finished at a third timing at which the supply of TESi for a predetermined period of time was completed;

a third step wherein a supply of ammonia (NH_3) is started either immediately after, or after the third timing at which the supply of TESi is finished, and the supply of NH_3 is finished at a fourth timing at which the supply of NH_3 for a predetermined period of time was completed; and

a fourth step wherein a purge time is started after the supply of NH_3 is finished at the fourth timing at which the supply of NH_3 was completed, and said purge time is finished at a fifth timing;

impurity pairs being formed as a donor-acceptor complex in said first and second steps using co-doping causing a decrease in

activation energy and an increase in carrier concentration in said crystal layer

said first through fourth steps being repeated a desired number of times.

26. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

supplying as one cycle each of said crystal raw materials, one at a time and separated by a purge time; and

supplying each of plural types of impurity raw materials for a given time, where the given time for supplying each of the impurity raw materials are close to each other;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

27. An impurity doping method for semiconductor wherein a crystal layer made of plural types of crystal raw materials is doped with impurities, comprising:

supplying as one cycle each of said plural types of crystal raw materials, one at a time and separated by a purge time; and

supplying each of plural types of impurity raw materials for a given time, wherein said given times either are at the same time of or after the start of supplying one of said crystal raw materials as well as before starting the supply of other of said crystal raw materials;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

28. An impurity doping method for semiconductor wherein a crystal layer made of plural types of crystal raw materials is doped with impurities comprising:

alternately supplying as a single cycle first and second crystal raw materials with purge times between the supply of the first crystal raw material and the supply of the second crystal raw material;

supplying a first impurity raw material and a second impurity raw material at given times which are close to one another and either at the same time of or after the start of

supplying of said first crystal raw material as well as before starting the supply of said second crystal raw material;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

29. The method according to claim 26, wherein said impurity raw materials are placed at a close relationship with each other at a predetermined ratio without incorporating disorder into said crystal layer.

30. The method according to claim 27, wherein said impurity raw materials are placed at a close relationship with each other at a predetermined ratio without incorporating disorder into said crystal layer.

31. The method according to claim 28, wherein said impurity raw materials are placed at a close relationship with each other at a predetermined ratio without incorporating disorder into said crystal layer.

32. The method according to claim 21, wherein Mg and Si are placed at a close relationship with each other at a predetermined ratio without incorporating disorder in a layer of Ga.

33. The method according to claim 26, wherein said impurity raw materials are supplied in a pulsed manner.

34. The method according to claim 27, wherein said impurity raw materials are supplied in a pulsed manner.

35. The method according to claim 28, wherein said impurity raw materials are supplied in a pulsed manner.

36. The method according to claim 21, wherein ($(Cp)_2Mg$) and said TESi are supplied in a pulsed manner.

APPENDIX B

EVIDENCE APPENDIX

None

APPENDIX C

RELATED PROCEEDINGS APPENDIX

None